# REVERSING THE SIGNALED MAGNITUDE EFFECT IN DELAYED MATCHING TO SAMPLE: DELAY-SPECIFIC REMEMBERING?

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Pigeons performed a delayed matching-to-sample task in which large or small reinforcers for correct remembering were signaled during the retention interval. Accuracy was low when small reinforcers were signaled, and high when large reinforcers were signaled (the signaled magnitude effect). When the reinforcer-size cue was switched from small to large partway through the retention interval, accuracy accordingly changed from low to high. The opposite happened when the cue was switched from large to small. This dissociation of forgetting from the passage of time raises the possibility that remembering is delay-specific. The reversal of the signaled magnitude effect during the retention interval is consistent with an attentional account in which the stimulus control of remembering is influenced by extraneous events.

*Key words:* forgetting, delay-specific remembering, signaled magnitude effect, delayed stimulus control, delayed matching to sample, pigeons

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The main characteristic of a memory task is the retention or delay interval between a prior event and the subsequent behavior it occasions. In delayed matching-to-sample, choice of one of two comparison stimuli is reinforced when the chosen stimulus matches the sample presented some time before the choice. In general, the discrimination is more difficult with longer delay intervals between the sample and the choice (White, 1985, 2001, in press; Wixted, 1989).

Longer delays, however, do not always result in a more difficult discrimination. Sargisson and White (2001) trained different groups of pigeons in a delayed matching task with a single delay of 0, 2, 4, or 6 s from the very beginning of training. When tested with a range of delays, matching tended to be most accurate at the original training delay, compared to shorter or longer delays. In another experiment where five delays were included within experimental sessions of a delayed matching task, White (2001) reinforced correct matching responses at all delays except one. Accuracy decreased at that delay, relative to shorter and longer delays. The reverse version of this study was reported by Nakagawa, Etheridge, Foster, Sumpter, and Temple (2004), who reinforced correct responses at a 4-s delay in a delayed matching-to-sample task, but not at 0-s or 16-s delays. Accuracy was higher at the 4-s delay than at the shorter or longer delays. These results

support the idea that remembering in delayed matching can be specific to a particular delay or retention interval. That is, remembering can be more accurate at one delay than at other shorter or longer delays, despite the fact that delay duration is varied unpredictably within the experimental session.

The possibility that remembering can be *delay-specific* follows from recognizing that the behavior of remembering is a discrimination performed at the time of choice (White, 2001, 2002). The discrimination is conjointly controlled by conditions prevailing at the time of choice, including delayed control by the temporally distant samples, the choice stimuli, and the reinforcement contingencies, as well as by the duration of the retention interval at the time of choice. The discrimination does not necessarily worsen with the passage of time, in spite of the usual result that forgetting functions show a systematic decrement with increasing time. Under appropriate conditions, accuracy at a longer retention interval can be either lower or higher than at a shorter retention interval in the same procedure, a result which White (2001) referred to as temporal independence. That is, with increasing retention-interval duration, forgetting functions can decrease (the usual result), increase, or be irregular with time. The discrimination between ''red at 4 s'' versus ''green at 4 s'', for example, is independent of the discrimination between ''red at 1 s versus green at 1 s''. The discrimination is delay-specific

in that it depends on the duration of the retention interval for the current trial. If a choice response was required at an earlier point in the retention interval, accuracy would not necessarily be higher because the discriminations at the different times in the retention interval are independent. In general, reversed forgetting functions provide evidence for delay-specific remembering because they demonstrate temporal independence and suggest a dissociation of forgetting from the passage of time.

The results of two earlier studies are consistent with delay-specific remembering in delayed matching-to-sample tasks. In these, each of two retention intervals was accompanied by a specific cue or signal. Wasserman, Grosch, and Nevin (1982) used different line orientations, or different auditory stimuli, to signal short and long retention intervals within sessions. Following training with the signaled-retention interval procedure, tests were conducted in which the relation between the signals and retention intervals was reversed. In their Experiment 2, accuracy was lower at the long retention interval during training, but during testing when the cues signaling retention-interval duration were reversed, accuracy was higher at the long retention interval than at the short retention interval. The same result was reported by McDonald and Grant (1987). In different experiments, McDonald and Grant showed that the effect of reversing the retention-interval cue did not depend on whether the signal overlapped the sample and continued into the delay as in the study by Wasserman et al., or whether the signal was presented only at the beginning of the retention interval. During training, accuracy was specific to short or long retention intervals, as shown by the effect of the cue reversal. In commenting on the result reported by McDonald and Grant, Wixted (1989, p. 416) noted:

> ''This interesting finding suggests that the strength of a discriminative stimulus may be delay specific when only one retention interval is employed. That is, a generalization gradient of discriminative strength may be conditioned around a particular delay such that it is strongest at the baseline delay and weaker at other delays (longer or shorter).''

Wixted thus astutely predicted the result reported over a decade later by Sargisson and White (2001).

In the present experiment we studied delay-specific remembering by reversing the cues in the procedure used to show the signaled magnitude effect. Unlike the cue reversal in the signaled-retention interval studies, we reversed the cue *partway* through the retention interval. We employed the delayed matching-to-sample procedure (Blough, 1959; White, in press) with pigeons. Two types of trials were mixed within session: large-reinforcer trials, and small-reinforcer trials. Different cues in the retention interval signaled the size of the reinforcer. Consistent with previous demonstrations of the signaled magnitude effect, accuracy was higher overall on trials where the large reinforcer was signaled than on trials where the small reinforcer was signaled (Brown & White, 2005a; Jones, White, & Alsop, 1995; McCarthy & Voss, 1995; Nevin & Grosch, 1990). Following extensive training to establish overall high and overall low levels of accuracy on trials with the two cues, the cues for large and small reinforcers were switched partway through the retention interval in novel switch trials. Interestingly, Nevin, Davison, Odum, & Shahan (2007) reported the result of a similar cue reversal in a multiple-schedule version of the delayed matching task where different cues signaled high or low reinforcer probabilities. Unlike in the present study, however, Nevin et al. reversed the cue for the entire duration of the retention interval. They were able to show a reversal of the signaled probability effect (Brown & White, 2005a). By reversing the cue partway through the retention interval, we asked whether the signaled magnitude effect would be evident for the first few seconds of the retention interval, but be reversed for the last few seconds.

## METHOD

### Subjects

Five adult homing pigeons (*Columba livia*) were housed in individual cages with free access to water and grit. They had previous experience in a similar procedure (Brown & White, 2005a). The holding room was illuminated naturally, supplemented with incandescent light on a 12-hour light/dark cycle. Following each daily experimental session, birds were fed enough mixed grain to maintain their weights at 85% ±10 g of their free-feeding weights.

## Apparatus

Experiments were conducted in five Med Associates experimental chambers, each 29.5 cm high, 29.5 cm wide, and 24.5 cm deep. Each chamber contained a row of three 2.1-cm diameter plexiglass response keys, 21 cm above the grid floor, spaced 6 cm apart, and which could be lit red or green. Center keys could also display white diagonal-cross or vertical-line symbols across their diameter against a dark background. Sufficiently strong (greater than $0.15°N$) pecks to red or green keys produced an audible relay click. Pecks to keys with symbols or to nonilluminated keys did not produce a click. Access to wheat reinforcers was provided by a movable hopper in an aperture 12.5 cm below the center key. The hopper was lit when wheat was available and an infrared beam sensed when a bird put its head above the hopper to feed. Reinforcer durations were timed from the point of entry of a bird's head in the hopper. The lights, hopper, infrared beam and recording of key-pecks to lit keys were all administered by a PC running Med-PC® for Windows.

## Procedure

Pigeons were tested in the same chamber and at the same time ($\pm 30$ min) every day of the week. Each trial began when a red or green sample was presented on the center key. Once the sample key was pecked five times, the center key displayed either a diagonal cross or a vertical line symbol. The vertical line was a cue to signal that 4.5-s access to wheat (large reinforcer) was available for correct choice responses. The diagonal cross was a cue that only 0.5-s access to wheat (small reinforcer) was available for correct choices. Observation by the experimenters indicated that a bird could obtain a grain of wheat on most instances where access to wheat (timed from entry of the bird's head to the hopper) was 0.5 s. As in studies of the differential outcome effect where outcomes can include food versus no food, the present use of very small versus large durations of food access was designed to optimize the signaled magnitude effect.

After the reinforcer-size cue had been displayed for a retention interval of 1, 2, 4, or 8 s, it was turned off following the first subsequent center-key peck. The center-key peck was required in order to facilitate stimulus control by the cue. Following the delay, one side key was illuminated red and the other green. When one of these side keys was pecked once, all key-lights were extinguished. Correct responses (pecks to colors that matched the sample) were immediately reinforced by either 4.5-s (large) or 0.5-s (small) access to wheat, as cued. Incorrect responses resulted in 4.5-s or 0.5-s blackout according to the cue. A dark 15-s intertrial interval followed each trial independently of its outcome.

Daily sessions could either be standard training sessions or occasional *test* sessions containing *switch trials*. Training sessions consisted of 96 trials, none of which were switch trials. Test sessions consisted of 128 trials. Half of these trials were randomly designated as switch trials. In switch trials, the cue (and the reinforcer size that it signaled) were swapped from line to cross, or from cross to line, after 2 s, thus affecting only 4-s and 8-s retention intervals. For 1-s and 2-s delay intervals, the reinforcer-size cue did not change during the delay, even if the delay was extended beyond the arranged 1-s or 2-s delay owing to a longer response latency. Independently of whether a trial was designated as a standard trial or a switch trial, and whether a correct response produced a large or small reinforcer, events on trials with 1-s and 2-s delays were identical, except for the reinforcer cue (large vs. small). That is, reinforcer cues on standard trials with delays of 1 s and 2 s could not be distinguished from reinforcer cues on trials designated as switch trials. Reinforcers delivered in switch trials were appropriate to the immediately-preceding cue. Within a session, trial types were selected randomly without replacement such that each combination of sample stimulus, reinforcer cue, choice pair, and—during test sessions—switch versus no switch designation, occurred the same number of times for each retention interval duration. If a pigeon's session did not finish within 50 min (for training sessions) or 75 min (for switch sessions), the session was terminated. The pigeons in the present experiment had been trained in the study reported by Brown and White (2005a), in a similar procedure but with reinforcer durations of 1 s and 4.5 s. One month after that experiment, daily sessions continued for a further year in the present procedure. Within the first 3 months, a few preliminary switch sessions were conducted to
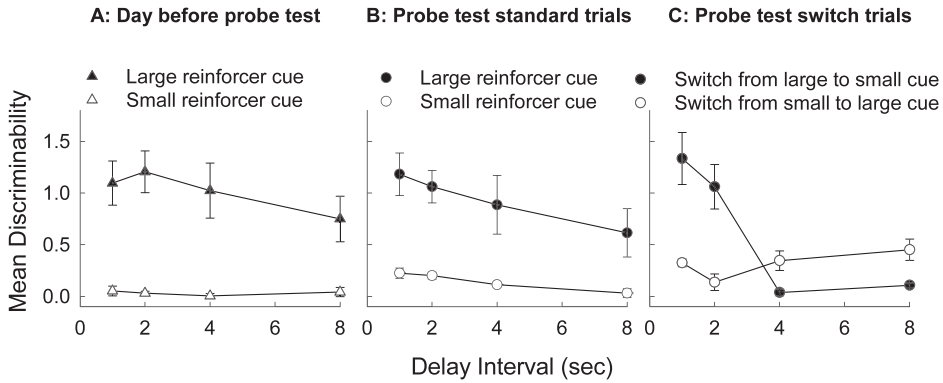
Fig. 1.   Mean discriminability as a function of delay interval for standard trials where small and large reinforcers were signaled by a cue present throughout the delay or retention interval on trials in the session before the probe tests (A) and in the probe tests (B), and for switch trials where the reinforcer-size cue was switched from small to large or from large to small immediately after 2 s in the retention interval (Panel C). Error bars are standard errors of the mean.

test the switch method but there were equipment malfunctions during that time. During the last 9 months, seven probe test sessions were conducted at least 1 month apart (46, 54, 37, 35, 52, and 36 days respectively before the following test session), except for the sixth test which was conducted in the session following the fifth test. The remainder of sessions were training sessions. Test sessions were interspersed among training sessions with low frequency in order to minimize the effect of reinforcing choices on switch trials on subsequent test performance.

## RESULTS

Accuracy at each retention interval was measured in terms of discriminability, log $d$ (Davison & Tustin, 1978; White, 1985). Log $d$ is calculated as the log (base 10) of the geometric mean of the ratios of correct (c) to error (e) responses following the red and green samples. That is, $\log d = .5*\mathrm{Log}((c_{red}/e_{red})*(c_{green}/e_{green}))$. It has the advantage of avoiding a ceiling effect associated with proportion correct which is bounded by 1.0 (Nevin & Grosch, 1990), and theoretically it is not influenced by response bias (Davison & Tustin, 1978). In order to avoid indeterminate ratios in cases where there were no errors, 0.5 was added to the response totals before log $d$ measures were calculated (Brown & White, 2005b).

For each bird, there was a total of 72 responses following red and green samples at

each delay and reinforcer cue over the six training sessions preceding the test sessions. Panel A in Figure 1 shows that mean discriminability was higher when the larger reinforcer was signalled than when the small reinforcer was signalled. This signalled magnitude effect repeats that found in previous studies (Brown & White, 2005a, 2009; Jones, White & Alsop, 1995; McCarthy & Voss, 1995; Nevin & Grosch, 1990). For each pigeon and at each delay, discriminability was clearly higher when the large reinforcer was signalled than when the small reinforcer was signalled, with the single exception of Bird Z3 at the 8-s retention interval where discriminability in the two conditions was the same. This signaled magnitude effect was also evident in the data from the standard trials in the seven test sessions, where responses summed to 56 for each combination of sample, delay interval, and reinforcer cue for each bird. Mean discriminability for the standard trials in test sessions (Figure 1, Panel B) closely corresponded to discriminability in the preceding training session (Panel A).

Panel C of Figure 1 shows the results for the switch trials in the probe test sessions. When the cue was switched from the large-reinforcer cue to the small-reinforcer cue after 2 s, discriminability was high at 1-s and 2-s delays and very low at 4-s and 8-s delays. Conversely, when the cue was switched from the small-reinforcer cue to the large-reinforcer cue after 2 s, discriminability was low at 1-s and 2-s delays, and higher at 4-s and 8-s delays. In

particular, the signaled magnitude effect at 1-s and 2-s delays was consistent with the effect in training and in standard trials in test sessions. At 4-s and 8-s delays, however, the signaled magnitude effect was reversed. The crossover of functions for the switch trials in Panel C of Figure 1 was evident for each of the individual birds, although the effect was relatively small for Bird Z3. For each bird, discriminability at 4-s and 8-s delays was always higher when the cue was switched from small to large than when it was switched from large to small.

Figure 2 shows discriminability at the different delays in the test sessions for individual birds. For all but one bird, when the reinforcer cue was switched from small to large (left panel), discriminabilty increased to the same level as that for the 8-s delay in standard large reinforcer-cue trials. The exception was Bird Z2 where there was nevertheless a substantial increase in discriminability when the cue was switched from small to large. In the right panel of Figure 2, switching the reinforcer cue from large to small caused discriminability to fall to the same level as for the 4-s and 8-s delays in standard small reinforcer-cue trials. The pattern was the same for each bird. Figure 2 shows that, at least by the 8-s delay, the signaled magnitude effect was reversed on switch trials in that discriminability increased or decreased to the same level as that on standard trials where large and small reinforcers were cued.

Figure 3 shows the same data for individual birds as in Figure 2, but reorganized to clarify the comparison between standard trials and switch trials that began with the same cue. When compared to the trials with the small reinforcer cue, the increase in discriminability across delays on test trials where the cue was switched from small to large seems smaller (right panel), compared to the relative decrease in discriminability when the cue was switched from large to small (left panel). (Note, however, that discriminabilty at 8 s could not be expected to be higher on the small-to-large switch trials than on the large reinforcer-cue trials.) When discriminability across the four delays (right panel) was compared between the small-to-large switch trials and the small reinforcer-cue trials in an analysis of variance for repeated measures on the factors of trial type and delay, there was a statistically significant interaction between trial
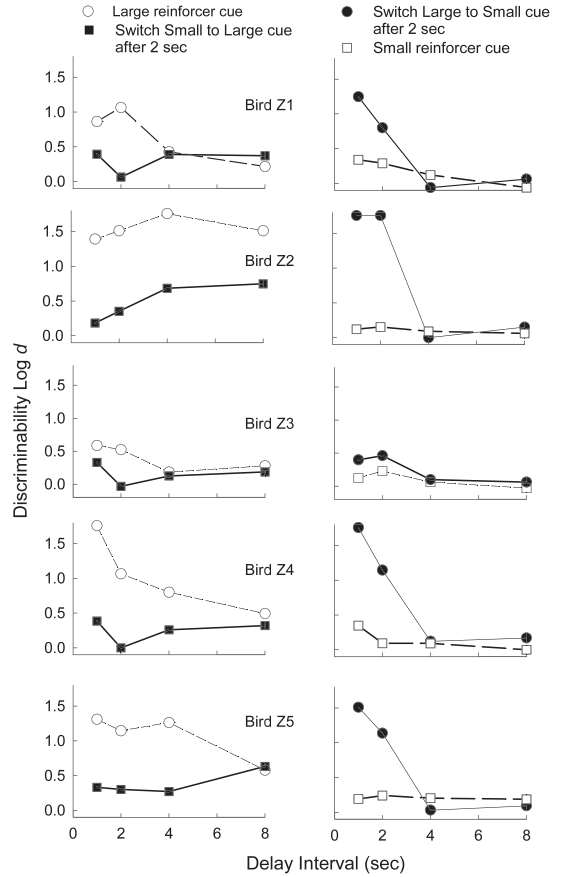


Fig. 2. Discriminability as a function of delay interval for probe test trials where large (left panel) or small (right panel) reinforcers were cued in the delay intervals of standard trials, and where reinforcer-size cues were switched from small to large (right panel) or large to small (left panel) after 2 s in the delay.

type and delay, $F(3, 12) = 16.32$, $p < .001$. Discriminability in the switch trials was overall higher than in the standard trials, $F(1, 4) = 9.10$, $p < .05$. Newman-Keuls post-hoc comparisons showed that discriminability for the two trial types did not differ at 1-s and 2-s delays, put did differ significantly at 4-s and 8-s delays. Additionally, discriminability at 4-s and 8-s delays was significantly higher than at the 1-s and 2-s delays in the switch trials. In these comparisons, and one including the function for the small reinforcer cue in the session conducted the day before the test, there were no differences in discriminability at the 2-s delay (see Figure 1, Panels A, B, C). In a further comparison between the functions for the small reinforcer cue in the standard trials
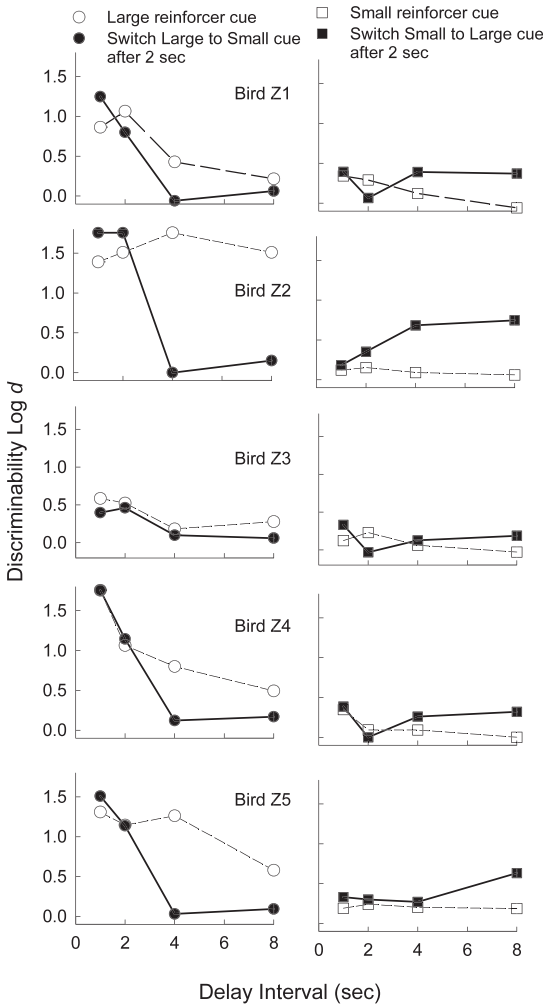
Fig. 3. Discriminability as a function of delay interval for probe test trials where large or small reinforcers were cued in the delay intervals of standard trials (unfilled symbols), and where reinforcer-size cues were switched from small to large or large to small after 2 s in the delay (filled symbols).
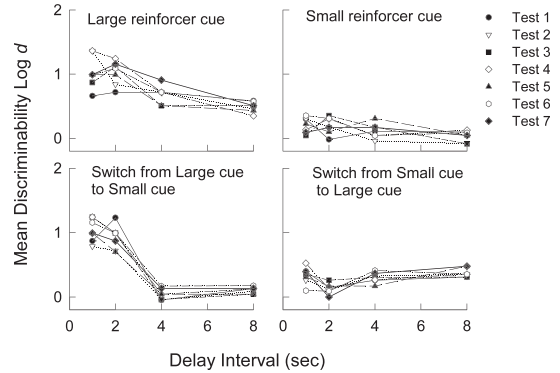


Fig. 4. Mean discriminability as a function of delay interval for standard trials in probe tests with small and large reinforcer cues and for switch trials where the cue was switched from large to small or small to large, for each of the seven probe tests.

in the test and the session conducted the day before, there were no significant differences at 2-s, 4-s, and 8-s delays, but discriminability at the 1-s delay was higher in the standard test trials than in trials conducted the day before, $p < .05$, a difference that was evident in the data for only 3 birds (Figure 3).

Figure 4 shows that the functions relating discriminability to delay on the four types of trials in the test sessions were consistent across test sessions. There was no evidence for a systematic or disruptive effect of reinforcing choice responses on probe switch trials. For each of the test sessions, when the reinforcer cue was switched from small to large, mean discriminability at the 8-s delay was higher than at 8 s when the cue was switched from large to small, and at 8 s on standard trials, when the small reinforcer was signaled. The signaled magnitude effect and its reversal were therefore consistent across test sessions.

## DISCUSSION

Forgetting functions depicting the decline in the accuracy of remembering with increasing retention-interval duration are influenced by reinforcer variables. Accuracy or discriminability is overall higher with greater probability or magnitude of reinforcement for correct choices in delayed matching to sample (Brown & White, 2009). When different reinforcer magnitudes are signaled during the retention intervals within sessions, the resulting signaled magnitude effect is manifest as clearly more accurate remembering on trials where the larger reinforcer is signaled (Nevin & Grosch, 1990). Nevin et al. (2007) reversed the signaled magnitude effect by reversing cues (relative to the baseline stimuli in their multiple-schedule procedure) across the entire retention interval. In the present experiment, by switching the cues signaling the reinforcer magnitudes partway through the retention interval, we showed that the signaled magnitude effect could effectively be reversed within the retention interval. Our result is consistent with that of Nevin et al., and in

addition demonstrates a delay-specific signaled magnitude effect. It is delay specific in that it occurs at longer delays independently of its occurrence at short delays, and vice versa. That is, the signaled magnitude effect at long delays was independent of whether there was a signaled magnitude effect at short delays on standard trials, or under reversal conditions, on switch trials.

In the signaled magnitude-effect procedure, the cue that signals reinforcer magnitude or probability has powerful stimulus control over remembering. Accurate remembering is high or low probability depending on the cue in the retention interval. Nevin et al. (2007, pp. 300–301) suggested that

> The effects of cue reversal on forgetting functions suggest that during the retention interval, the pigeons are engaged in some sort of behavior that came under stimulus control by cues signaling high or low reinforcer probabilities. Whatever they were doing (what we have called ''attending'' here) affected discrimination accuracy in a way consistent with reinforcer probabilities signaled during the pigeons' extensive histories…

It might well be the case, as Nevin et al. (2007) suggest, that attending is accompanied by overt behavior during the retention interval, or more generally, that remembering is a discrimination under control of stimuli from a variety of sources, including the reinforcer-size signal (White, 2001; 2002). Indeed, the seminal study of delayed matching to sample by Blough (1959) over 50 years ago indicated a clear role for behavior during the retention interval. The quantitative model of attending to samples and comparisons during the retention interval described by Nevin et al. accounts well for a switch in attention during the retention interval. Put simply, on test trials where the small-reinforcer cue is presented at the outset, the pigeon no longer attends to the samples or comparisons. But after a few seconds, when the cue is switched to the one signaling the large reinforcer, the pigeon now pays attention to the samples and comparisons. Thus there is an increase in discriminability from short retention intervals to long retention intervals on small-to-large switch trials. The important element in this stimulus control account is the choice available to the individual: attending to the task (which has an extended duration from sample presentation to later choice), versus engaging in alternative behaviors. Brown and White (2005c) made such a choice explicit by scheduling reinforcers for a task as an alternative to delayed matching. The result was that as the alternative-task reinforcement rate increased, discriminability in the delayed matching task decreased. Cues that signal larger reinforcers control greater attention to the remembering task. Even when the cue is switched partway through the retention interval, attention to the task of remembering can be reduced, or increased, at different stages in the retention interval. The switch in attention (or stimulus control) between the remembering task and other unrelated tasks does not depend on the passage of time, and is therefore consistent with the dissociation of forgetting from time.

Two aspects of the present result support the conclusion that the signaled magnitude effect can be delay-specific. The first is that the difference in discriminability between large and small reinforcer-cue conditions can be specific to short or long retention intervals, consistent with the stimulus-control account described above. The second is the increase in discriminability from short to long retention intervals in the small-to-large switch probe test, that is, a reversal of the forgetting function. This second aspect is important because, a ''gradient of discriminative strength'', in Wixted's (1989) terms, would be shown by an irregular forgetting function in which there is an increase in discriminability to a certain delay, followed by a decrease (cf. Sargisson & White, 2001). The decrease is easily understood as the result of increasing temporal distance, or perhaps as generalization from a training stimulus at a 0-s delay (Rayburn-Reeves & Zentall, 2009), but an increase is less usual.

The increase in discriminability from short retention intervals to long retention intervals on small-to-large switch trials in the present experiment, at least from the 2-s delay (Figure 3), contrasts with the typical forgetting function. The increasing function for Bird Z2 in Figures 2 and 3 is the clearest individual instance in the present study. An increase in discriminability at longer retention intervals has been reported in the few studies summarized in the introduction above (McDonald & Grant, 1987; Nakagawa et al., 2004; Sargisson & White, 2001; Wasserman et al., 1982; White,

2001). Possibly the only clear example of increased accuracy at longer delays in human short-term memory was reported by Turvey, Brick and Osborn (1970), with a replication by Greene (1996). They used the Peterson and Peterson (1959) procedure in a between-groups design. In the first four recall trials, different groups of participants experienced different retention intervals—either 5, 10, 15, 20, or 25 s depending on the group. In the fifth recall trial, however, all groups experienced the same retention interval duration, 15 s. Two results are of interest. First, across the different groups, accuracy on the second trial increased with increasing delay duration. Second, accuracy on the fifth trial with the 15-s delay was greatest for the groups who previously experienced the longest delays (20 s and 25 s). This second result is analogous to the result reported by Sargisson and White (2001) for pigeons in the delayed matching-to-sample task.

The results reported by Turvey et al. (1970) are often cited in order to cast doubt on trace decay as an account of forgetting (Surprenant & Neath, 2009). In one of the first short-term memory studies with humans (Peterson & Peterson, 1959), the passage of time was emphasized as the main determinant of forgetting. Time was supposed to generate forgetting through a combination of trace decay and an inability to maintain rehearsal behaviors. Berman, Jonides, and Lewis (2009) showed that, in a human short-term memory task, items from the previous trial strongly influenced performance on the current trial in the absence of trace decay of the prior-trial items, and without transfer of rehearsal of the prior-trial items to the current trial. Such dissociations of forgetting from the passage of time question trace decay as an account of forgetting (Laming & Scheiwiller, 1985; Nairne, 2002). The present result, along with the previous demonstrations of delay-specific remembering, similarly question a trace-decay account of forgetting, especially as it might apply to delayed stimulus control in nonhuman animals.

## REFERENCES

Berman, M. G., Jonides, J., & Lewis, R. L. (2009). In search of decay in verbal short-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 25*, 317–333.

Blough, D. S. (1959). Delayed matching in the pigeon. *Journal of the Experimental Anaylsis of Behavior, 2*(2), 151–160.

Brown, G. S., & White, K. G. (2005a). On the effects of signaling reinforcer probability and magnitude. *Journal of the Experimental Analysis of Behavior, 83*, 119–128.

Brown, G. S., & White, K. G. (2005b). The optimal correction for estimating extreme discriminability. *Behavior Research Methods, 37*, 436–449.

Brown, G. S., & White, K. G. (2005c). Remembering: The role of extraneous reinforcement. *Learning & Behavior, 33*, 309–323.

Brown, G. S., & White, K. G. (2009). Reinforcer probability, reinforcer magnitude, and the reinforcement context for remembering. *Journal of Experimental Psychology: Animal Behavior Processes, 35*, 238–249.

Davison, M. C., & Tustin, R. D. (1978). The relation between the generalized matching law and signal-detection theory. *Journal of the Experimental Analysis of Behavior, 51*, 291–315.

Green, R. L. (1996). The influence of experimental design: The example of the Brown-Peterson paradigm. *Canadian Journal of Experimental Psychology, 50*, 240–242.

Jones, B. M., White, K. G., & Alsop, B. (1995). On two effects of signaling the consequences for remembering. *Animal Learning & Behavior, 23*, 256–272.

Laming, D., & Scheiwiller, P. (1985). Retention in perceptual memory: A review of models and data. *Perception & Psychophysics, 37*, 189–197.

McCarthy, D., & Voss, P. (1995). Delayed matching-to-sample performance: Effects of relative reinforcer frequency and of signaled versus unsignaled reinforcer magnitudes. *Journal of the Experimental Analysis of Behavior, 63*, 33–51.

McDonald, S. E., & Grant, D. S. (1987). Effects of signaling retention interval length on delayed matching-to-sample in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes, 13*, 116–125.

Nairne, J. S. (2002). Remembering over the short-term: The case against the standard model. *Annual Review of Psychology, 53*, 53–81.

Nakagawa, S., Etheridge, R. J. M., Foster, T. M., Sumpter, C. E., & Temple, W. (2004). The effects of changes in consequences on hens' performance in delayed-matching-to-sample tasks. *Behavioural Processes, 67*, 441–451.

Nevin, J. A., Davison, M., Odum, A. L., & Shahan, T. A. (2007). A theory of attending, remembering, and reinforcement in delayed matching to sample. *Journal of the Experimental Analysis of Behavior, 88*, 285–317.

Nevin, J. A., & Grosch, J. (1990). Effects of signaled reinforcer magnitude on delayed matching-to-sample performance. *Journal of Experimental Psychology: Animal Behavior Processes, 16*, 298–305.

Peterson, L. R., & Peterson, M. (1959). Short-term retention of individual items. *Journal of Experimental Psychology, 58*, 193–198.

Rayburn-Reeves, R., & Zentall, T. R. (2009). Animal memory: The contribution of generalization decrement to delayed conditional discrimination retention functions. *Learning & Behavior, 37*, 299–304.

Sargisson, R. J., & White, K. G. (2001). Generalization of delayed matching-to-sample performance following training at different delays. *Journal of the Experimental Analysis of Behavior, 75*, 1–14.

Surprenant, A. M., & Neath, I. (2009). *Principles of memory.* NY: Psychology Press.

Turvey, M. T., Brick, P., & Osborn, J. (1970). Proactive interference in short-term memory as a function of prior-item retention interval. *Quarterly Journal of Experimental Psychology, 22,* 142–147.

Wasserman, E. A., Grosch, J., & Nevin, J. A. (1982). Effects of signaled retention intervals on pigeon short-term memory. *Animal Learning & Behavior, 10,* 330–338.

White, K. G. (1985). Characteristics of forgetting functions in delayed matching to sample. *Journal of the Experimental Analysis of Behavior, 44,* 15–34.

White, K. G. (2001). Forgetting functions. *Animal Learning & Behavior, 29,* 193–207.

White, K. G. (2002). Psychophysics of remembering: The discrimination hypothesis. *Current Directions in Psychological Science, 11,* 141–145.

White, K. G. (in press). Remembering and forgetting. In G. Madden (Ed.), *Handbook of behavior analysis.* NY: APA Books.

Wixted, J. T. (1989). Nonhuman short-term memory: A quantitative reanalysis of selected findings. *Journal of the Experimental Analysis of Behavior, 52,* 409–426.